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SUBJECT: Advanced Life Support System Experiment for AAP - Case 620

DATE: March 31, 1969

FROM: W. W. Hough
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ABSTRACT

The many concepts for advanced, closed-loop life support systems have been surveyed to determine if AAP can aid in their development by performing a flight experiment. Only concepts that cannot be tested on the ground should be tested in space, and the only element of the space environment (which affects life support system operation) that cannot be duplicated on the ground for more than a minute is zero-g. Inflight demonstration of a particular subsystem is not necessarily desirable as such demonstration can dictate the operational application of the particular subsystem rather than a more optimum one that performs the same function.

As a result of the survey, it has been concluded that the only additional things that <u>should</u> be tested in AAP are:

1. Liquid/gas phase separation techniques.

2. Techniques for maintenance of liquid loops.

3. A zero-g whole body shower.

4. An esthetically acceptable waste collection system.

A concept for an experiment which accomplishes the first three at a weight of about 300 pounds and no-power penalty is presented. The fourth is being done to some degree in the AAP habitability experiment, and it is unlikely that a better system would meet medical objectives.

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MEMORANDUM FOR FILE

One of the useful outputs of the Apollo Applications Program will be experiment data that will aid us in taking the next step to longer duration manned missions. Many of the AAP experiments concern medical studies of man to determine his capability in and compatibility with long-duration space flight. Few are aimed at investigating concepts or components of advanced life support systems (LSS). Mr. Schneider, AAP Director, has asked what AAP can do, in the form of a flight experiment, to aid the development of advanced, closed-loop life support systems. To attempt to answer the question, the authors have reviewed many concepts and proposed configurations to see if there are any subsystems, components, or physical concepts that should be tested in actual long-duration space flight.

Ground Rules

There are several specific, related ground rules that the authors used in conducting the study.

1. It makes sense to fly an experiment only if the experiment cannot be performed on the ground.

2. The only orbital-environment element (which might influence LSS performance) that cannot be duplicated on the ground for periods of more than a minute is zero-g.

3. The concept of flight-rating a particular subsystem by flying it first as an experiment is undesirable if it can be flight-rated on the ground.

The idea behind ground rule No. 3 is that in most areas of advanced LSS there are many competing concepts (e.g., Bosch vs. Sabatier vs. molten carbonate CO_2 reductions), and that it is too early to choose a particular subsystem. If we fly a particular subsystem, even as an experiment, we tend to lock ourselves into it.

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Survey

The survey of many life support system concepts indicates that most of the development problems have not been connected with zero-g, but rather have been due to corrosion, bacteria growth, and unreliable instrumentation. The basic processes in most systems avoid g-dependent operation and thus they do not need zero-g testing. Where there is an uncertainty about zero-g operation, it is almost always due to a single factor -- uncertainty about liquid/gas phase separation mechanics in zero-g. Surface tension is the underlying principle in most phase separation techniques. The capillary forces in wick separators, the hydrophobic/hydrophilic membranes with different "wetting" characteristics, and the bladderless SPS propellant tanks all depend on surface tension for their operation. Extended duration testing of critical phase separation techniques should be performed to validate extensive ground based studies.

A problem somewhat related to phase separation is maintainability of a liquid loop in zero-g. To replace a component, the liquid loop must be broken and bubbles of the cabin atmosphere can be trapped in the fluid when the system is reassembled. A demonstration of feasibility of zero-g liquid-loop maintenance would be very helpful, as successful long-duration operation of advanced life support systems will probably require such operations.

There appear to be only two specific life support systems where long term zero-g experience is desirable in proving feasibility and where the concern is not directly related to phase separation. These are an aesthetically acceptable biowaste collection system and a whole-body shower. The AAP habitability experiment will include a urine and fecal collection systems, and although there is argument as to whether they are aesthetically acceptable, it is doubtful that another type of system (such as the General Electric fecal slinger) would meet the objectives of the medical experiment which calls for return of dried fecal matter. A whole-body shower is not included in AAP, and it is possible that a shower experiment could be combined with a maintainable water recovery system that uses several zero-g phase separation techniques. A conceptual design for such an experiment is shown in the Figure.

Zero-g Shower/Water Reclamation/Maintainability Experiment Description

The experiment consists of a zero-g whole body shower which utilizes a directed air flow with an entrained water spray. The air/water stream passes through a perforated floor to a hydrophobic/hydrophilic (or equivalent) liquid/gas phase separator. The gas stream is recycled. The separated waste water is pumped into an accumulator, and then passed through a multifiltration/ion-exchange system for purification. The processed water is then passed through a silver-ion generator, and stored in a bladderless tank that depends on surface tension for water retention. The reclaimed water is then pumped from the tank to the zero-g shower. Provision is made to inject a cleansing agent directly into the liquid spray. A heater, controlled from within the shower compartment, is included on the inlet line to achieve comfortable water temperatures.

The multifiltration system consists of a series of filters for removing odor, color, particulate matter, and bacteria from the waste water. The silver ion generator acts as an additional safeguard in preventing bacteria from reaching the storage tank. The system is configured so that defective filters can be replaced or repaired (cleaned) by the crew. This entails appropriate instrumentation and valving to detect and isolate a clogging filter.

A water quality monitor is placed in the storage tank to indicate if impure water should be recycled without an astronaut present in the shower. Makeup water can be added directly in the shower compartment. Bubble traps might be required upstream of each pump to prevent the equivalent of "vapor-lock." These traps may be hydrophobic/hydrophilic phase separators similar in design to the water separator in the shower exit stream.

The crew is an integral part of this experiment. Their reaction to the zero-g shower is basic to the development of a whole-body cleansing system for long-duration missions. The crew is also required to maintain the closed loop system -- particularly the multifiltration unit -- in operating order. The expected maintenance tasks are sufficiently simple so as not to require extensive crew training, but realistic enough that the concept and techniques of liquid-loop maintainability can be verified.

The experiment interfaces with the spacecraft in two subsystem areas. Electrical power is required for operating two water pumps, a fan, a heater, and the instrumentation associated with the multifiltration unit. The experiment can be operated when other power using systems are inoperative, and will therefore not incur a power penalty. The second interface is with the spacecraft structural system and consists of mounting provisions required for the experiment. A preliminary estimate of the total weight penalty is 300 pounds.

Conclusions

A review of the many concepts for closed-loop life support systems has indicated that the only additional things that <u>should</u> be tested in AAP are:

1. Liquid/gas phase separation techniques.

2. Maintainability of liquid-loops.

3. A zero-g whole body shower.

4. An aesthetically acceptable waste collection system.

A concept for an experiment which accomplishes the first three at a weight of about 300 pounds and no power penalty has been presented. The fourth is being done to some degree in the existing habitability experiment, and it is unlikely that a better system would meet medical objectives.

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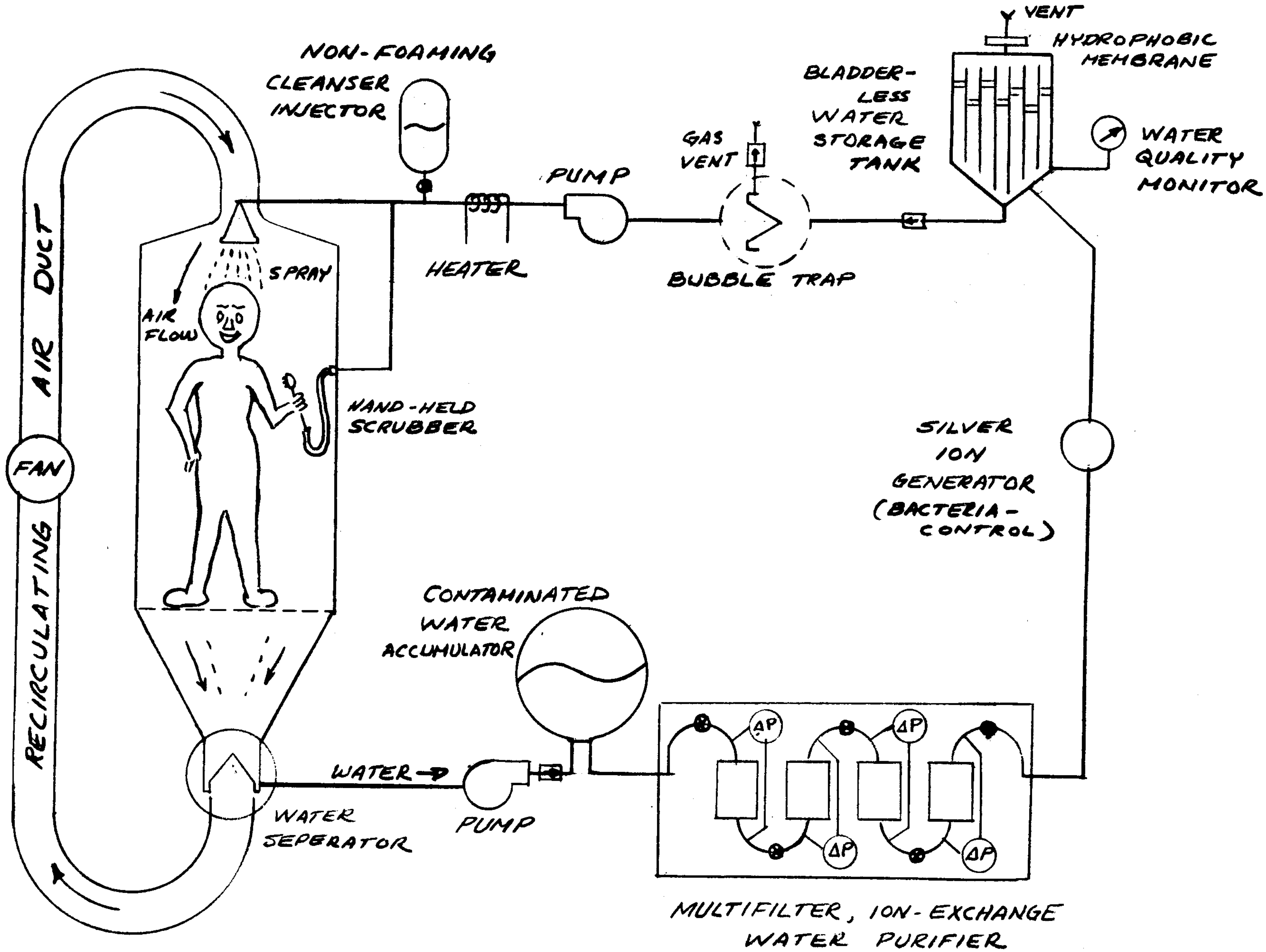
ZERO-G SHOWER / WATER RECLAMATION / MAINTAINABILITY EXPT.



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